

4.3.3.2.1.9 Public and Occupational Health and Safety

This section describes the radiological and hazardous chemical releases and their associated impacts resulting from either normal operation or accidents involved with the ceramic immobilization facility. The section first describes the impacts from normal facility operation at each potential site, followed by a description of impacts from facility accidents.

Summaries of the radiological impacts to the public and to workers associated with normal operation of the immobilization facility during the assumed 10-year campaign time are presented in Tables 4.3.3.2.1.9–1 and 4.3.3.2.1.9–2, respectively. [Text deleted.] Impacts from hazardous chemicals to these same groups are given in Table 4.3.3.2.1.9–3. Summaries of impacts associated with postulated accidents are given in Tables 4.3.3.2.1.9–4 through Table 4.3.3.2.1.9–9. Detailed results are presented in Section M.

Normal Operation. There would be no radiological releases during the construction of a ceramic immobilization facility at any of the sites analyzed. Construction worker exposures to material potentially contaminated with radioactivity (for example, from construction activities involved with existing contaminated soil) would be limited to assure that doses are maintained ALARA. Toward this end, construction workers would be monitored as appropriate. Limited hazardous chemical releases are anticipated as a result of construction activities. However, concentrations would be within the regulated exposure limits. During normal operation, there would be both radiological and hazardous chemical releases to the environment and also direct in-plant exposures. The resulting doses and potential health effects to the public and workers at each site are described below.

Radiological Impacts. Radiological impacts to the average and maximally exposed members of the public resulting from the normal operation of the ceramic immobilization facility at each of the sites are presented in Table 4.3.3.2.1.9–1. The impacts from all site operations, including the ceramic immobilization facility, are also given. To put operational doses into perspective, comparisons with doses from natural background radiation are included in the table.

The doses to the maximally exposed member of the public from annual ceramic immobilization facility operation range from 1.6×10^{-8} mrem at the NTS site to 5.9×10^{-7} mrem at the ORR site. From 10 years of operation, the corresponding risks of fatal cancer to this individual would range from 8.0×10^{-14} to 3.0×10^{-12} . The impacts to the average individual would be less. As a result of annual facility operations, the population doses would range 3.3×10^{-8} person-rem at the NTS site to 1.2×10^{-5} person-rem at the SRS site. The corresponding numbers of fatal cancers in these populations from 10 years of operation would range from 1.7×10^{-10} to 6.0×10^{-8} .

The doses to the maximally exposed member of the public from annual total site operations are all within the radiological limits specified in NESHAPS (40 CFR 61, Subpart H) and DOE Order 5400.5, and would range from 6.1×10^{-5} mrem at Pantex to 3.2 mrem at ORR. From 10 years of operation, the corresponding risks of fatal cancers to this individual would range from 3.1×10^{-10} to 1.6×10^{-5} . The impacts to the average individual would be less. This activity would be included in a program to ensure that doses to the public are ALARA. As a result of annual total site operation, the population doses would be within the limit in proposed 10 CFR 834, and would range from 2.8×10^{-4} person-rem at Pantex to 44 person-rem at the SRS site. The corresponding numbers of fatal cancers in these populations from 10 years of operation would range from 1.4×10^{-6} to 0.22.

Doses to onsite workers from normal operations are given in Table 4.3.3.2.1.9–2. Included are involved workers directly associated with the ceramic immobilization facility, workers who are not involved with the ceramic immobilization facility, and the entire workforce at each site. All doses fall within regulatory limits.

The annual dose to ceramic immobilization facility workers is site-independent and would be 244 mrem to the average facility worker and 110 person-rem to the entire facility workforce. The annual dose to the average

Table 4.3.3.2.1.9-1. Potential Radiological Impacts to the Public During Normal Operation of the Ceramic Immobilization Facility (For Borehole)—Immobilized Disposition Alternative

Receptor	Hanford		NTS		INEL		Pantex		ORR		SRS	
	Total Site ^a	Facility	Total Site ^a	Facility	Total Site ^a	Facility						
Annual Dose to the Maximally Exposed Individual Member of the Public^b												
Atmospheric release pathway (mrem)	3.2x10 ⁻⁸	4.4x10 ⁻³	1.6x10 ⁻⁸	4.2x10 ⁻³	2.0x10 ⁻⁸	0.018	2.5x10 ⁻⁷	6.1x10 ⁻⁵	5.9x10 ⁻⁷	1.5	1.8x10 ⁻⁷	0.42
Drinking water pathway (mrem)	0	0	0	0	0	0	0	0	0	0.10	0	0.081
Total liquid release pathway (mrem)	0	9.5x10 ⁻⁴	0	0	0	0	0	0	0	1.7	0	0.37
Atmospheric and liquid release pathways combined (mrem)	3.2x10 ⁻⁸	5.3x10 ⁻³	1.6x10 ⁻⁸	4.2x10 ⁻³	2.0x10 ⁻⁸	0.018	2.5x10 ⁻⁷	6.1x10 ⁻⁵	5.9x10 ⁻⁷	3.2	1.8x10 ⁻⁷	0.79
Percent of natural background ^c	1.1x10 ⁻⁸	1.8x10 ⁻³	5.1x10 ⁻⁹	1.3x10 ⁻³	5.9x10 ⁻⁹	5.2x10 ⁻³	7.5x10 ⁻⁸	1.8x10 ⁻⁵	2.0x10 ⁻⁷	1.1	6.0x10 ⁻⁸	0.27
10-year fatal annual cancer risk	1.6x10 ⁻¹³	2.7x10 ⁻⁸	8.0x10 ⁻¹⁴	2.1x10 ⁻⁸	1.0x10 ⁻¹³	8.9x10 ⁻⁸	1.3x10 ⁻¹²	3.1x10 ⁻¹⁰	3.0x10 ⁻¹²	1.6x10 ⁻⁵	9.0x10 ⁻¹³	4.0x10 ⁻⁶
Annual Population Dose Within 30 Kilometers^d												
Atmospheric release pathway (person-rem)	1.5x10 ⁻⁶	0.46	3.3x10 ⁻⁸	3.7x10 ⁻³	2.3x10 ⁻⁷	2.4	6.3x10 ⁻⁷	2.8x10 ⁻⁴	1.1x10 ⁻⁵	29	1.2x10 ⁻⁵	40
Total liquid release pathway (person-rem)	0	1.1	0	0	0	0	0	0	0	4.7	0	3.6
Atmospheric and liquid release pathways combined (person-rem)	1.5x10 ⁻⁶	1.6	3.3x10 ⁻⁸	3.7x10 ⁻³	2.3x10 ⁻⁷	2.4	6.3x10 ⁻⁷	2.8x10 ⁻⁴	1.1x10 ⁻⁵	34	1.2x10 ⁻⁵	44
Percent of natural background ^c	8.0x10 ⁻¹⁰	8.4x10 ⁻⁴	3.6x10 ⁻¹⁰	4.0x10 ⁻⁵	2.5x10 ⁻¹⁰	2.7x10 ⁻³	5.4x10 ⁻¹⁰	2.4x10 ⁻⁷	2.9x10 ⁻⁹	9.0x10 ⁻³	4.5x10 ⁻⁹	0.017
10-year fatal cancers	7.5x10 ⁻⁹	7.8x10 ⁻³	1.7x10 ⁻¹⁰	1.9x10 ⁻⁵	1.2x10 ⁻⁹	0.012	3.2x10 ⁻⁹	1.4x10 ⁻⁶	5.5x10 ⁻⁸	0.17	6.0x10 ⁻⁸	0.22

Table 4.3.3.2.1.9-1. Potential Radiological Impacts to the Public During Normal Operation of the Ceramic Immobilization Facility (For Borehole)—Immobilized Disposition Alternative—Continued

Receptor	Hanford			NTS			INEL			Pantex			ORR			SRS		
	Facility	Total	Site ^a	Facility	Total	Site ^a	Facility	Total	Site ^a	Facility	Total	Site ^a	Facility	Total	Site ^a	Facility	Total	Site ^a
Annual Dose to the Average Individual Within 80 Kilometers^e																		
Atmospheric and liquid release pathways combined (mrem)	2.4x10 ⁻⁹	2.6x10 ⁻³	1.1x10 ⁻⁹	1.3x10 ⁻⁴	8.6x10 ⁻¹⁰	8.9x10 ⁻³	1.8x10 ⁻⁹	8.0x10 ⁻⁷	8.6x10 ⁻⁹	4.0x10 ⁻¹⁵	4.3x10 ⁻¹²	4.3x10 ⁻¹⁴	1.3x10 ⁻⁷	6.7x10 ⁻¹⁴	2.5x10 ⁻⁷			
10-year fatal cancer risk	1.2x10 ⁻¹⁴	1.3x10 ⁻⁸	5.6x10 ⁻¹⁵	6.3x10 ⁻¹⁰	4.3x10 ⁻¹⁵	4.5x10 ⁻⁸	9.0x10 ⁻¹⁵	4.0x10 ⁻¹²	4.3x10 ⁻¹⁴	1.3x10 ⁻⁷	6.7x10 ⁻¹⁴	2.5x10 ⁻⁷						

^a Includes impacts from No Action facilities (refer to Sections 4.2.1.9 through 4.2.6.9). The location of the maximally exposed individual may be different under No Action than for operation of the ceramic immobilization facility. Therefore, the impacts may not be directly additive.

^b The applicable radiological limits for an individual member of the public from total site operations are: 10 mrem per year from the air pathways, as required by NESHAPS (40 CFR 61, Subpart H) under the CAA; 4 rem per year from the drinking water pathway, as required by the SDWA; and 100 mrem per year from all pathways combined. Refer to DOE Order 5400.5.

^c The annual natural background radiation levels: (1) Hanford: the average individual receives 300 mrem; the population within 80 km receives 186,400 person-rem, (2) NTS: the average individual receives 313 mrem; the population within 80 km receives 9,190 person-rem, (3) INEL: the average individual receives 338 mrem; the population within 80 km receives 90,800 person-rem, (4) Pantex: the average individual receives 334 mrem; the population within 80 km receives 116,900 person-rem, (5) ORR: the average individual receives 295 mrem; the population within 80 km receives 379,000 person-rem, (6) SRS: the average individual receives 298 mrem; the population within 80 km receives 266,000 person-rem.

^d For DOE activities, proposed 10 CFR 834 (see 58 FR 16268) would generally limit the potential annual population dose to 100 person-rem from all pathways combined, and would require an ALARA program.
[Text deleted.]

^e Obtained by dividing the population dose by the number of people projected to be living within 80 km (50 mi) of the site (621,000 at Hanford, 29,400 at NTS, 269,000 at INEL, 350,000 at Pantex, 1,285,000 at ORR, and 893,000 at SRS).

Source: Section M.2.

Table 4.3.3.2.1.9-2. Potential Radiological Impacts to Workers During Normal Operation of the Ceramic Immobilization Facility (For Borehole)—Immobilized Disposition Alternative

Receptor	Hanford	NTS	INEL	Pantex	ORR	SRS
Involved Workforce^a						
Average worker dose (mrem/yr) ^b	244	244	244	244	244	244
10-year risk of fatal cancer	9.8x10 ⁻⁴					
Total dose (person-rem/yr)	110	110	110	110	110	110
10-year fatal cancers	0.44	0.44	0.44	0.44	0.44	0.44
Noninvolved Workforce^c						
Average worker dose (mrem/yr) ^b	27	5.0	30	10	2.6	32
10-year risk of fatal cancer	1.1x10 ⁻⁴	2.0x10 ⁻⁵	1.2x10 ⁻⁴	4.0x10 ⁻⁵	1.0x10 ⁻⁵	1.3x10 ⁻⁴
Total dose (person-rem/yr)	250	3.0	220	14	44	226
10-year fatal cancers	1.0	0.012	0.88	0.056	0.18	0.90
Total Site Workforce^d						
Dose (person-rem/yr)	360	113	330	124	154	336
10-year fatal cancers	1.4	0.45	1.3	0.50	0.62	1.3

^a The involved worker is a worker associated with operations of the ceramic immobilization facility.

^b The radiological limit for an individual worker is 5,000 mrem/year (10 CFR 835). However, DOE has also established an administrative control level of 2,000 mrem per year (DOE 1992); the sites must make reasonable attempts to maintain worker doses below this level.

^c The noninvolved worker is a worker onsite but not associated with operations of the ceramic immobilization facility. The noninvolved workforce is equivalent to the No Action workforce.

^d The impact to the total site workforce is the summation of the involved worker impact and the noninvolved worker impact.
[Text deleted.]

Source: Section M.2.

noninvolved worker would range from 2.6 mrem at the ORR site to 32 mrem at the SRS site. The annual total dose to all noninvolved workers would range from 3.0 person-rem at NTS to 250 person-rem at the Hanford site. The annual dose to the total site workforces would range from 113 person-rem at NTS to 360 person-rem at Hanford. The risks and numbers of fatal cancers among the different workers from 10 years of operation are included in Table 4.3.3.2.1.9–2. Dose to individual workers would be kept low by instituting badged monitoring and ALARA programs and also workers rotations. As a result of the implementation of these mitigation resources, the actual number of fatal cancers calculated would be lower for the operation of this facility.

Hazardous Chemical Impacts. The hazardous chemical impacts to the public resulting from normal operation of the ceramic immobilization without radionuclides facility at each of several sites are presented in Table 4.3.3.2.1.9–3. Included is the impact due only to operation of the ceramic immobilization facility and the site's total hazardous chemical impact. The total site impacts are provided to demonstrate the estimated level of health effects expected and the risk of cancer due to the total chemical exposures on each site. All supporting impact analyses are provided in Section M.3.

The HI to the MEI ranges from 2.3×10^{-4} at the NTS site to 9.1×10^{-3} at the ORR site due to the facility operation. The cancer risk from hazardous chemicals to the MEI is zero at all sites. The HI to the onsite worker ranges from 7.2×10^{-2} at Pantex to 0.15 at ORR, and the cancer risk to the onsite worker is zero (because no carcinogens are released from hazardous chemicals) at all sites.

Facility Accidents. A set of potential accidents have been postulated for a ceramic immobilization without radionuclides facility for which there may be releases of Pu that may impact onsite workers and the offsite population. The accident consequences and risks to a worker located 1,000 m (3,280 ft) from the accident release point, the maximum offsite individual located at the site boundary, and the population located within 80 km (50 mi) of the accident release point are summarized in Tables 4.3.3.2.1.9–4 through 4.3.3.2.1.9–9 for the sites analyzed (Hanford, NTS, INEL, Pantex, ORR, and SRS). In the event that the site boundary is less than 1,000 m (3,280 ft) from the accident release point, the worker is placed at the site boundary. For the set of accidents analyzed, the maximum number of cancer fatalities in the population within 80 km (50 mi) would be 6.3×10^{-4} at ORR for the calciner feed criticality accident scenario with a probability of 1.0×10^{-5} per year. The corresponding 10 year facility lifetime risk from the same accident scenario for the population, maximum offsite individual, and worker at 1,000 m (3,280 ft), would be 6.3×10^{-8} , 2.9×10^{-10} , and 1.3×10^{-9} , respectively. The maximum population 10-year facility lifetime risk would be 6.3×10^{-8} (that is, one fatality in over 1 million years) at ORR for the calciner feed criticality accident scenario with a probability of 1.0×10^{-5} per year. The corresponding maximum offsite individual and worker 10 year facility lifetime risks would be 2.9×10^{-10} and 1.3×10^{-9} , respectively. Section M.5 presents additional facility accident data and summary descriptions of the accident scenarios identified in Tables 4.3.3.2.1.9–4 through 4.3.3.2.1.9–9.

The location of workstations, number of workers, personnel protective features, engineered safety features, and other design details affect the extent of worker exposures to accidents. Certain accidents such as fires, explosions, and criticality could cause fatalities to workers close to the accident. Prior to construction and operation of a new facility, DOE orders require detailed safety analyses to assure that facility designs and operation procedures limit the number of workers in hazardous areas and minimize risk of injury or fatality in the event of an accident.

Aircraft Crash. The probability of an aircraft crash into a new ceramic immobilization facility at Pantex will depend upon its specific location relative to the airport and airplane traffic patterns. In the future, there is a possibility that air traffic patterns may change and cause a change in the probability of a crash into a specific facility. [Text deleted.] A discussion of aircraft crash accidents for this PEIS is contained in Appendix R.

Table 4.3.3.2.1.9-3. Potential Hazardous Chemical Impacts to the Public and Workers During Normal Operation of the Ceramic Immobilization Facility (For Borehole)—Immobilized Disposition Alternative

Receptor	Hanford		NTS		INTEL		Paintex		ORR		SRS	
	Total Facility ^a	Site ^b	Total Facility ^a	Site ^b	Total Facility ^a	Site ^b	Total Facility ^a	Site ^b	Total Facility ^a	Site ^b	Total Facility ^a	Site ^b
Maximally Exposed Individual (Public)												
Hazard Index ^c	1.6x10 ⁻³	1.6x10 ⁻³	2.3x10 ⁻⁴	2.3x10 ⁻⁴	3.3x10 ⁻³	0.019	8.7x10 ⁻³	0.014	9.1x10 ⁻³	0.049	4.2x10 ⁻⁴	5.6x10 ⁻³
Cancer Risk ^d	0	0	0	0	3.6x10 ⁻⁶	0	1.1x10 ⁻⁸	0	0	0	0	1.3x10 ⁻⁷
Worker Onsite												
Hazard Index ^e	0.14	0.14	0.074	0.074	0.14	0.37	0.072	0.078	0.15	0.30	0.13	1.3
Cancer Risk ^f	0	0	0	0	7.7x10 ⁻⁴	0	4.5x10 ⁻⁷	0	0	0	0	1.9x10 ⁻⁴

^a Facility=Contribution from the proposed new facility operation only.

^b Total=Includes the contributions from the No Action and the proposed new facility operation.

^c Hazard Index for MEI=sum of individual Hazard Quotients (noncancer health effects) for MEI.

^d Cancer Risk for MEI=(emissions concentrations) x (0.286 [converts concentrations to doses]) x (Slope Factor). Where there are no known carcinogens among the hazardous chemicals emitted, therefore the calculated cancer risk value is 0.

^e Hazard Index for Workers=sum of individual Hazard Quotients (noncancer health effects) for workers.

^f Cancer Risk for workers=(emissions for 8-hr) x (0.286 [converts concentrations to doses]) x (0.237 [fraction of year exposed]) x (0.571 [fraction of lifetime working]) x (Slope Factor). Where there are no known carcinogens among the hazardous chemicals emitted, there are no Slope Factors, therefore the calculated cancer risk value is 0.

Source: Section M.3, Tables M.3.4-41 through M.3.4-46.

Table 4.3.3.2.1.9-4. Ceramic Immobilization Facility (For Borehole) for Immobilized Disposition Alternative—Accident Impacts at Hanford Site

Accident Description	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Risk of Cancer Fatality ^a (per 10 yr) ^a	Probability of Cancer Fatality ^b (per 10 yr) ^a	Risk of Cancer Fatality ^b (per 10 yr) ^a	Probability of Cancer Fatality ^b (per 10 yr) ^a	Risk of Cancer Fatalities ^c (per 10 yr) ^a	Number of Cancer Fatalities ^c (per yr)
Earthquake	2.3x10 ⁻¹³	2.3x10 ⁻⁹	2.3x10 ⁻¹⁵	2.3x10 ⁻¹¹	1.6x10 ⁻¹¹	1.6x10 ⁻⁷
Glovebox fire	2.3x10 ⁻¹³	2.3x10 ⁻⁹	2.3x10 ⁻¹⁵	2.3x10 ⁻¹¹	1.6x10 ⁻¹¹	1.6x10 ⁻⁷
Glovebox nuclear criticality	1.4x10 ⁻¹⁰	1.4x10 ⁻⁶	1.2x10 ⁻¹²	1.2x10 ⁻⁸	1.6x10 ⁻⁹	1.6x10 ⁻⁵
Calciner feed tank nuclear criticality	1.4x10 ⁻⁹	1.4x10 ⁻⁵	1.2x10 ⁻¹¹	1.2x10 ⁻⁷	1.6x10 ⁻⁸	1.6x10 ⁻⁴
Ceramic can drop	5.7x10 ⁻¹⁶	5.7x10 ⁻¹⁴	5.7x10 ⁻¹⁸	5.7x10 ⁻¹⁶	4.1x10 ⁻¹⁴	4.1x10 ⁻¹²
Pellet container breakage	5.7x10 ⁻¹⁸	5.7x10 ⁻¹⁶	5.7x10 ⁻²⁰	5.7x10 ⁻¹⁸	4.1x10 ⁻¹⁶	4.1x10 ⁻¹⁴
Dissolver spill	1.4x10 ⁻¹⁵	2.7x10 ⁻¹⁵	1.4x10 ⁻¹⁷	2.7x10 ⁻¹⁷	1.0x10 ⁻¹³	2.0x10 ⁻¹³
Calciner feed spill	4.0x10 ⁻¹⁵	7.9x10 ⁻¹⁵	4.0x10 ⁻¹⁷	7.9x10 ⁻¹⁷	2.9x10 ⁻¹³	5.8x10 ⁻¹³
Calciner product spill	1.0x10 ⁻¹²	2.0x10 ⁻¹²	1.0x10 ⁻¹⁴	2.0x10 ⁻¹⁴	7.2x10 ⁻¹¹	1.4x10 ⁻¹⁰
Sintering furnace explosion	3.4x10 ⁻¹³	3.4x10 ⁻⁸	3.4x10 ⁻¹⁵	3.4x10 ⁻¹⁰	2.5x10 ⁻¹¹	2.5x10 ⁻⁶
Uncontrolled chemical reaction	1.6x10 ⁻¹⁴	1.6x10 ⁻⁹	1.6x10 ⁻¹⁶	1.6x10 ⁻¹¹	1.2x10 ⁻¹²	1.2x10 ⁻⁷
Nuclear criticality	1.4x10 ⁻¹¹	1.4x10 ⁻⁶	1.2x10 ⁻¹³	1.2x10 ⁻⁸	1.6x10 ⁻¹⁰	1.6x10 ⁻⁵
Expected risk ^d	1.5x10 ⁻⁹	—	1.3x10 ⁻¹¹	—	1.8x10 ⁻⁸	—

^a The risk values are calculated by multiplying the probability of cancer fatality (for the worker at 1,000 m or the maximum offsite individual) or the number of cancer fatalities (for the population to 80 km) by the accident frequency and the number of years of operation.

^b Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^c Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km is exposed to the indicated dose. The value assumes the accident has occurred.

^d Expected risk is the sum of the risks over the lifetime of the facility.

Source: Calculated using the source terms in Tables M.5.3.7.1-3 and M.5.3.7.1-4 and the MACCSC computer code.

Table 4.3.3.2.1.9-5. Ceramic Immobilization Facility (For Borehole) for Immobilized Disposition Alternative—Accident Impacts at Nevada Test Site

Accident Description	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km		
	Risk of Cancer Fatality ^a (per 10 yr) ^a	Probability of Cancer Fatality ^b (per 10 yr) ^a	Risk of Cancer Fatality ^b	Probability of Cancer Fatality ^b	Cancer Fatalities ^c (per 10 yr) ^a	Cancer Fatalities ^c	Accident Frequency (per yr)
Earthquake	1.6x10 ⁻¹³	1.6x10 ⁻⁹	3.6x10 ⁻¹⁵	3.6x10 ⁻¹¹	3.7x10 ⁻¹³	3.7x10 ⁻⁹	1.0x10 ⁻⁵
Glovebox fire	1.6x10 ⁻¹³	1.6x10 ⁻⁹	3.6x10 ⁻¹⁵	3.6x10 ⁻¹¹	3.7x10 ⁻¹³	3.7x10 ⁻⁹	1.0x10 ⁻⁵
Glovebox nuclear criticality	1.0x10 ⁻¹⁰	1.0x10 ⁻⁶	2.3x10 ⁻¹²	2.3x10 ⁻⁸	3.3x10 ⁻¹¹	3.3x10 ⁻⁷	1.0x10 ⁻⁵
Calciner feed tank nuclear criticality	1.0x10 ⁻⁹	1.0x10 ⁻⁵	2.3x10 ⁻¹¹	2.3x10 ⁻⁷	3.3x10 ⁻¹⁰	3.3x10 ⁻⁶	1.0x10 ⁻⁵
Ceramic can drop	3.9x10 ⁻¹⁶	3.9x10 ⁻¹⁴	9.0x10 ⁻¹⁸	9.0x10 ⁻¹⁶	9.3x10 ⁻¹⁶	3.3x10 ⁻¹⁴	1.0x10 ⁻³
Pellet container breakage	3.9x10 ⁻¹⁸	3.9x10 ⁻¹⁶	9.0x10 ⁻²⁰	9.0x10 ⁻¹⁸	9.3x10 ⁻¹⁸	9.3x10 ⁻¹⁶	1.0x10 ⁻³
Dissolver spill	9.3x10 ⁻¹⁶	1.9x10 ⁻¹⁵	2.2x10 ⁻¹⁷	4.3x10 ⁻¹⁷	2.2x10 ⁻¹⁵	4.5x10 ⁻¹⁵	0.05
Calciner feed spill	2.7x10 ⁻¹⁵	5.4x10 ⁻¹⁵	6.3x10 ⁻¹⁷	1.3x10 ⁻¹⁶	6.5x10 ⁻¹⁵	1.3x10 ⁻¹⁴	0.05
Calciner product spill	6.8x10 ⁻¹³	1.4x10 ⁻¹²	1.6x10 ⁻¹⁴	3.1x10 ⁻¹⁴	1.6x10 ⁻¹²	3.3x10 ⁻¹²	0.05
Sintering furnace explosion	2.3x10 ⁻¹³	2.3x10 ⁻⁸	5.4x10 ⁻¹⁵	5.4x10 ⁻¹⁰	5.6x10 ⁻¹³	5.6x10 ⁻⁸	1.0x10 ⁻⁶
Uncontrolled chemical reaction	1.1x10 ⁻¹⁴	1.1x10 ⁻⁹	2.5x10 ⁻¹⁶	2.5x10 ⁻¹¹	2.6x10 ⁻¹⁴	2.6x10 ⁻⁹	1.0x10 ⁻⁶
Nuclear criticality	1.0x10 ⁻¹¹	1.0x10 ⁻⁶	2.3x10 ⁻¹³	2.3x10 ⁻⁸	3.3x10 ⁻¹²	3.3x10 ⁻⁷	1.0x10 ⁻⁶
Expected risk ^d	1.1x10 ⁻⁹	—	2.5x10 ⁻¹¹	—	3.6x10 ⁻¹⁰	—	—

^a The risk values are calculated by multiplying the probability of cancer fatality (for the worker at 1,000 m or the maximum offsite individual) or the number of cancer fatalities (for the population to 80 km) by the accident frequency and the number of years of operation.

^b Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^c Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km is exposed to the indicated dose. The value assumes the accident has occurred.

^d Expected risk is the sum of the risks over the lifetime of the facility.

Source: Calculated using the source terms in Tables M.5.3.7.1-3 and M.5.3.7.1-4 and the MACCS computer code.

Table 4.3.3.2.1.9-6. Ceramic Immobilization Facility (For Borehole) for Immobilized Disposition Alternative—Accident Impacts at Idaho National Engineering Laboratory

Accident Description	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Risk of Cancer Fatality (per 10 yr) ^a	Probability of Cancer Fatality ^b (per 10 yr) ^a	Risk of Cancer Fatality (per 10 yr) ^a	Probability of Cancer Fatality ^b (per 10 yr) ^a	Risk of Cancer Fatalities ^c (per 10 yr) ^a	Number of Cancer Fatalities ^c
Earthquake	2.1x10 ⁻¹³	2.1x10 ⁻⁹	2.3x10 ⁻¹⁵	2.3x10 ⁻¹¹	4.9x10 ⁻¹²	4.9x10 ⁻⁸
Glovebox fire	2.1x10 ⁻¹³	2.1x10 ⁻⁹	2.3x10 ⁻¹⁵	2.3x10 ⁻¹¹	4.9x10 ⁻¹²	4.9x10 ⁻⁸
Glovebox nuclear criticality	1.4x10 ⁻¹⁰	1.4x10 ⁻⁶	3.5x10 ⁻¹²	1.3x10 ⁻⁸	4.3x10 ⁻¹⁰	4.3x10 ⁻⁶
Calciner feed tank nuclear criticality	1.4x10 ⁻⁹	1.4x10 ⁻⁵	1.3x10 ⁻¹¹	1.3x10 ⁻⁷	4.3x10 ⁻⁹	4.3x10 ⁻⁵
Ceramic can drop	5.3x10 ⁻¹⁶	5.3x10 ⁻¹⁴	5.7x10 ⁻¹⁸	5.7x10 ⁻¹⁶	1.2x10 ⁻¹⁴	1.2x10 ⁻¹²
Pellet container breakage	5.3x10 ⁻¹⁸	5.3x10 ⁻¹⁶	5.7x10 ⁻²⁰	5.7x10 ⁻¹⁸	1.2x10 ⁻¹⁶	1.2x10 ⁻¹⁴
Disolver spill	1.3x10 ⁻¹⁵	2.5x10 ⁻¹⁵	1.4x10 ⁻¹⁷	2.8x10 ⁻¹⁷	3.0x10 ⁻¹⁴	5.9x10 ⁻¹⁴
Calciner feed spill	3.7x10 ⁻¹⁵	7.4x10 ⁻¹⁵	4.0x10 ⁻¹⁷	8.0x10 ⁻¹⁷	8.7x10 ⁻¹⁴	1.7x10 ⁻¹³
Calciner product spill	9.3x10 ⁻¹³	1.9x10 ⁻¹²	1.0x10 ⁻¹⁴	2.0x10 ⁻¹⁴	2.2x10 ⁻¹¹	4.3x10 ⁻¹¹
Sintering furnace explosion	3.2x10 ⁻¹³	3.2x10 ⁻⁸	3.4x10 ⁻¹⁵	3.4x10 ⁻¹⁰	7.4x10 ⁻¹²	7.4x10 ⁻⁷
Uncontrolled chemical reaction	1.5x10 ⁻¹⁴	1.5x10 ⁻⁹	1.6x10 ⁻¹⁶	1.6x10 ⁻¹¹	3.5x10 ⁻¹³	3.5x10 ⁻⁸
Nuclear criticality	1.4x10 ⁻¹¹	1.4x10 ⁻⁶	1.3x10 ⁻¹³	1.3x10 ⁻⁸	4.3x10 ⁻¹¹	4.3x10 ⁻⁶
Expected risk ^d	1.5x10 ⁻⁹	—	1.5x10 ⁻¹¹	—	4.8x10 ⁻⁹	—

^a The risk values are calculated by multiplying the probability of cancer fatality (for the worker at 1,000 m or the maximum offsite individual) or the number of cancer fatalities (for the population to 80 km) by the accident frequency and the number of years of operation.

^b Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^c Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km is exposed to the indicated dose. The value assumes the accident has occurred.

^d Expected risk is the sum of the risks over the lifetime of the facility.

Source: Calculated using the source terms in Tables M.5.3.7.1-3 and M.5.3.7.1-4 and the MACCS computer code.

Table 4.3.3.2.1.9-7. Ceramic Immobilization Facility (For Borehole) for Immobilized Disposition Alternative—Accident Impacts at Pantex Plant

Accident Description	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Risk of Cancer Fatality ^a (per 10 yr) ^a	Probability of Cancer Fatality ^b (per 10 yr) ^a	Risk of Cancer Fatality ^b	Probability of Cancer Fatality ^b	Risk of Cancer Fatalities ^c (per 10 yr) ^a	Number of Cancer Fatalities ^c (per yr)
Earthquake	9.1x10 ⁻¹⁴	9.1x10 ⁻¹⁰	2.6x10 ⁻¹⁴	2.6x10 ⁻¹⁰	5.6x10 ⁻¹²	5.6x10 ⁻⁸
Glovebox fire	9.1x10 ⁻¹⁴	9.1x10 ⁻¹⁰	2.6x10 ⁻¹⁴	2.6x10 ⁻¹⁰	5.6x10 ⁻¹²	5.6x10 ⁻⁸
Glovebox nuclear criticality	6.2x10 ⁻¹¹	6.2x10 ⁻⁷	2.2x10 ⁻¹¹	2.2x10 ⁻⁷	9.5x10 ⁻¹⁰	9.5x10 ⁻⁶
Calciner feed tank nuclear criticality	6.2x10 ⁻¹⁰	6.2x10 ⁻⁶	2.2x10 ⁻¹⁰	2.2x10 ⁻⁶	9.5x10 ⁻⁹	9.5x10 ⁻⁵
Ceramic can drop	2.3x10 ⁻¹⁶	2.3x10 ⁻¹⁴	6.6x10 ⁻¹⁷	6.6x10 ⁻¹⁵	1.4x10 ⁻¹⁴	1.0x10 ⁻³
Pellet container breakage	2.3x10 ⁻¹⁸	2.3x10 ⁻¹⁶	6.6x10 ⁻¹⁹	6.6x10 ⁻¹⁷	1.4x10 ⁻¹⁶	1.4x10 ⁻¹⁴
Dissolver spill	5.5x10 ⁻¹⁶	1.1x10 ⁻¹⁵	1.6x10 ⁻¹⁶	3.2x10 ⁻¹⁶	3.4x10 ⁻¹⁴	6.7x10 ⁻¹⁴
Calciner feed spill	1.6x10 ⁻¹⁵	3.2x10 ⁻¹⁵	4.6x10 ⁻¹⁶	9.2x10 ⁻¹⁶	9.8x10 ⁻¹⁴	2.0x10 ⁻¹³
Calciner product spill	4.0x10 ⁻¹³	8.0x10 ⁻¹³	1.2x10 ⁻¹³	2.3x10 ⁻¹³	2.5x10 ⁻¹¹	4.9x10 ⁻¹¹
Sintering furnace explosion	1.4x10 ⁻¹³	1.4x10 ⁻⁸	4.0x10 ⁻¹⁴	4.0x10 ⁻⁹	8.5x10 ⁻¹²	8.5x10 ⁻⁷
Uncontrolled chemical reaction	6.4x10 ⁻¹⁵	6.4x10 ⁻¹⁰	1.9x10 ⁻¹⁵	1.9x10 ⁻¹⁰	3.9x10 ⁻¹³	3.9x10 ⁻⁸
Nuclear criticality	6.2x10 ⁻¹²	6.2x10 ⁻⁷	2.2x10 ⁻¹²	2.2x10 ⁻⁷	9.5x10 ⁻¹¹	9.5x10 ⁻⁶
Expected risk ^d	6.9x10 ⁻¹⁰	—	2.4x10 ⁻¹⁰	—	1.1x10 ⁻⁸	—

^a The risk values are calculated by multiplying the probability of cancer fatality (for the worker at 1,000 m or the maximum offsite individual) or the number of cancer fatalities (for the population to 80 km) by the accident frequency and the number of years of operation.

^b Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^c Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km is exposed to the indicated dose. The value assumes the accident has occurred.

^d Expected risk is the sum of the risks over the lifetime of the facility.

Source: Calculated using the source terms in Tables M.5.3.7.1-3 and M.5.3.7.1-4 and the MACCS computer code.

Table 4.3.3.2.1.9-8. Ceramic Immobilization Facility (For Borehole) for Immobilized Disposition Alternative—Accident Impacts at Oak Ridge Reservation

Accident Description	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Risk of Cancer Fatality ^a (per 10 yr) ^a	Probability of Cancer Fatality ^b (per 10 yr) ^a	Risk of Cancer Fatality ^b (per 10 yr) ^a	Probability of Cancer Fatality ^b (per 10 yr) ^a	Risk of Cancer Fatalities ^c (per 10 yr) ^a	Cancer Fatalities ^c (per yr)
Earthquake	2.1x10 ⁻¹³	2.1x10 ⁻⁹	4.6x10 ⁻¹⁴	4.6x10 ⁻¹⁰	4.0x10 ⁻¹¹	4.0x10 ⁻⁷
Glovebox fire	2.1x10 ⁻¹³	2.1x10 ⁻⁹	4.6x10 ⁻¹⁴	4.6x10 ⁻¹⁰	4.0x10 ⁻¹¹	4.0x10 ⁻⁷
Glovebox nuclear criticality	1.3x10 ⁻¹⁰	1.3x10 ⁻⁶	2.9x10 ⁻¹¹	2.9x10 ⁻⁷	6.3x10 ⁻⁹	6.3x10 ⁻⁵
Calciner feed tank nuclear criticality	1.3x10 ⁻⁹	1.3x10 ⁻⁵	2.9x10 ⁻¹⁰	2.9x10 ⁻⁶	6.3x10 ⁻⁸	6.3x10 ⁻⁴
Ceramic can drop	5.3x10 ⁻¹⁶	5.3x10 ⁻¹⁴	1.2x10 ⁻¹⁶	1.2x10 ⁻¹⁴	1.0x10 ⁻¹³	1.0x10 ⁻³
Pellet container breakage	5.3x10 ⁻¹⁸	5.3x10 ⁻¹⁶	1.2x10 ⁻¹⁸	1.2x10 ⁻¹⁶	1.0x10 ⁻¹⁵	1.0x10 ⁻³
Dissolver spill	1.3x10 ⁻¹⁵	2.5x10 ⁻¹⁵	2.8x10 ⁻¹⁶	5.5x10 ⁻¹⁶	2.4x10 ⁻¹³	4.8x10 ⁻¹³
Calciner feed spill	3.7x10 ⁻¹⁵	7.3x10 ⁻¹⁵	8.1x10 ⁻¹⁶	1.6x10 ⁻¹⁵	7.0x10 ⁻¹³	1.4x10 ⁻¹²
Calciner product spill	9.2x10 ⁻¹³	1.8x10 ⁻¹²	2.0x10 ⁻¹³	4.0x10 ⁻¹³	1.7x10 ⁻¹⁰	3.5x10 ⁻¹⁰
Sintering furnace explosion	3.2x10 ⁻¹³	3.2x10 ⁻⁸	6.9x10 ⁻¹⁴	6.9x10 ⁻⁹	6.0x10 ⁻¹¹	6.0x10 ⁻⁶
Uncontrolled chemical reaction	1.5x10 ⁻¹⁴	1.5x10 ⁻⁹	3.2x10 ⁻¹⁵	3.2x10 ⁻¹⁰	2.8x10 ⁻¹²	2.8x10 ⁻⁷
Nuclear criticality	1.3x10 ⁻¹¹	1.3x10 ⁻⁶	2.9x10 ⁻¹²	2.9x10 ⁻⁷	6.3x10 ⁻¹⁰	6.3x10 ⁻⁵
Expected risk ^d	1.4x10 ⁻⁹	—	3.2x10 ⁻¹⁰	—	7.0x10 ⁻⁸	—

^a The risk values are calculated by multiplying the probability of cancer fatality (for the worker at 1,000 m or the maximum offsite individual) or the number of cancer fatalities (for the population to 80 km) by the accident frequency and the number of years of operation.

^b Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^c Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km is exposed to the indicated dose. The value assumes the accident has occurred.

^d Expected risk is the sum of the risks over the lifetime of the facility.

Source: Calculated using the source terms in Tables M.5.3.7.1-3 and M.5.3.7.1-4 and the MACCS computer code.

Table 4.3.3.2.1.9-9. Ceramic Immobilization Facility (For Borehole) for Immobilized Disposition Alternative—Accident Impacts at Savannah River Site

Accident Description	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Risk of Cancer Fatality ^a (per 10 yr) ^a	Probability of Cancer Fatality ^b (per 10 yr) ^a	Risk of Cancer Fatality ^b (per 10 yr) ^a	Probability of Cancer Fatality ^b (per 10 yr) ^a	Risk of Cancer Fatalities ^c (per 10 yr) ^a	Number of Cancer Fatalities ^c (per yr)
Earthquake	1.5x10 ⁻¹³	1.5x10 ⁻⁹	3.6x10 ⁻¹⁵	3.6x10 ⁻¹¹	1.8x10 ⁻¹¹	1.8x10 ⁻⁷
Glovebox fire	1.5x10 ⁻¹³	1.5x10 ⁻⁹	3.6x10 ⁻¹⁵	3.6x10 ⁻¹¹	1.8x10 ⁻¹¹	1.8x10 ⁻⁷
Glovebox nuclear criticality	9.1x10 ⁻¹¹	9.1x10 ⁻⁷	2.0x10 ⁻¹²	2.0x10 ⁻⁸	2.0x10 ⁻⁹	2.0x10 ⁻⁵
Calciner feed tank nuclear criticality	9.1x10 ⁻¹⁰	9.1x10 ⁻⁶	2.0x10 ⁻¹¹	2.0x10 ⁻⁷	2.0x10 ⁻⁸	2.0x10 ⁻⁴
Ceramic can drop	3.7x10 ⁻¹⁶	3.7x10 ⁻¹⁴	9.1x10 ⁻¹⁸	9.1x10 ⁻¹⁶	4.4x10 ⁻¹⁴	4.4x10 ⁻¹²
Pellet container breakage	3.7x10 ⁻¹⁸	3.7x10 ⁻¹⁶	9.1x10 ⁻²⁰	9.1x10 ⁻¹⁸	4.4x10 ⁻¹⁶	4.4x10 ⁻¹⁴
Dissolver spill	8.9x10 ⁻¹⁶	1.8x10 ⁻¹⁵	2.2x10 ⁻¹⁷	4.4x10 ⁻¹⁷	1.1x10 ⁻¹³	2.1x10 ⁻¹³
Calciner feed spill	—	2.6x10 ⁻¹⁵	6.4x10 ⁻¹⁷	1.3x10 ⁻¹⁶	3.1x10 ⁻¹³	6.2x10 ⁻¹³
Calciner product spill	6.5x10 ⁻¹³	1.3x10 ⁻¹²	1.6x10 ⁻¹⁴	3.2x10 ⁻¹⁴	7.8x10 ⁻¹¹	1.6x10 ⁻¹⁰
Sintering furnace explosion	2.2x10 ⁻¹³	2.2x10 ⁻⁸	5.5x10 ⁻¹⁵	5.5x10 ⁻¹⁰	2.7x10 ⁻¹¹	2.7x10 ⁻⁶
Uncontrolled chemical reaction	1.0x10 ⁻¹⁴	1.0x10 ⁻⁹	2.6x10 ⁻¹⁶	2.6x10 ⁻¹¹	1.2x10 ⁻¹²	1.0x10 ⁻⁶
Nuclear criticality	9.1x10 ⁻¹²	9.1x10 ⁻⁷	2.0x10 ⁻¹³	2.0x10 ⁻⁸	2.0x10 ⁻¹⁰	2.0x10 ⁻⁵
Expected risk ^d	1.0x10 ⁻⁹	—	2.2x10 ⁻¹¹	—	2.3x10 ⁻⁸	—

^a The risk values are calculated by multiplying the probability of cancer fatality (for the worker at 1,000 m or the maximum offsite individual) or the number of cancer fatalities (for the population to 80 km) by the accident frequency and the number of years of operation.

^b Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^c Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km is exposed to the indicated dose. The value assumes the accident has occurred.

^d Expected risk is the sum of the risks over the lifetime of the facility.

Source: Calculated using the source terms in Tables M.5.3.7.1-3 and M.5.3.7.1-4 and the MACCS computer code.

- | An indication of the magnitude of the impacts of an aircraft crash into a ceramic immobilization facility is given by the earthquake scenario. The earthquake and aircraft scenarios are similar in that they both result in major structural damage and the release of plutonium directly to the environment. They differ in that an earthquake induced fire is based on limited combustible materials while the aircraft crash has the potential for a major fuel-related fire. Also, the earthquake has the potential for damage and release of hazardous materials throughout the facility while the aircraft crash may only damage and release hazardous materials in the vicinity of the point of impact. In both scenarios, the involved workers located within the facility could receive fatal injuries.
- | [Text deleted.]